Bipolar Transistor Design

$N_A := 6.023 \cdot 10^{23} \cdot \frac{1}{\text{mole}}$

$k_B := 1.38 \cdot 10^{-23} \cdot \frac{\text{joule}}{\text{K}}$

$e := 1.6 \cdot 10^{-19} \cdot \text{coul}$

$h := 6.63 \cdot 10^{-34} \cdot \text{J} \cdot \text{s}$

$\mu\text{m} := 10^{-6} \cdot \text{m}$

$\varepsilon_o := 8.85 \cdot 10^{-12} \cdot \frac{\text{F}}{\text{m}}$

$m_e := 9.11 \cdot 10^{-31} \cdot \text{kg}$

$\text{pF} := 10^{-9} \cdot \text{F}$

By further integration of Poisson's equation we can show (see Question 6.3) that the contact potential ϕ is given by

$$\phi = \frac{e}{2\varepsilon\varepsilon_0}\left(N_d l_n^2 + N_a l_p^2\right) \qquad (6.6)$$

Rearranging this expression and using the relationship in eqn (6.5) we can also show (see Question 6.4) that the depletion layer width on the p-type side is

$$l_p = \left(\frac{\phi 2\varepsilon\varepsilon_0}{eN_a}\frac{N_d}{N_a+N_d}\right)^{1/2} \qquad (6.7)$$

and that on the n-type side is

$$l_n = \left(\frac{\phi 2\varepsilon\varepsilon_0}{eN_d}\frac{N_a}{N_a+N_d}\right)^{1/2} \qquad (6.8)$$

Properties of Silicon

$E_g := 1.12 \cdot \text{e} \cdot \text{V}$ $\quad \varepsilon := 11.7$ $\quad T := 298 \cdot \text{K}$

$\mu_n := 0.14 \cdot \frac{\text{m}^2}{\text{V} \cdot \text{s}}$ $\quad m'_e := 0.43 \cdot m_e$ $\quad m'_h := 0.54 \cdot m_e$

$n_i := 2 \cdot \left(\frac{2 \cdot \pi \cdot m'_e \cdot k_B \cdot T}{h^2}\right)^{\frac{3}{2}} \cdot \exp\left(\frac{-E_g}{2 \cdot k_B \cdot T}\right)$ Intrinsic Conductivity $\quad n_i = 2.41 \times 10^{15}\,\frac{1}{\text{m}^3}$

$N_a := 10^{18} \cdot \frac{1}{\text{m}^3}$ Acceptor Dopant Conc. in p-doped region.

$N_d := 10^{18} \cdot \frac{1}{\text{m}^3}$ Donor Dopant Conc. in n-doped region.

$l_{P\_D} := 50 \cdot \mu\text{m}$ Hole Diffusion Distance

$$? ?? \frac{k_B ?T}{e} ?\ln ? \frac{N_a ?N_d}{n_i^2} ?$$

$$? \; ? \; 0.31\,V$$

Depletion Thicknesses

$$l_n ?? ? \frac{? ? ?2 ?? ??_o}{e ?N_d} ? \frac{N_a}{N_a ? N_d} ?^{\frac{1}{2}}$$

$$l_n \; ? \; 1.416 ? 10^{? 5}\,m$$

$$l_p ?? ? \frac{? ? ?2 ?? ??_o}{e ?N_a} ? \frac{N_d}{N_a ? N_d} ?^{\frac{1}{2}}$$

$$l_p \; ? \; 1.416 ? 10^{? 5}\,m$$

$$W ?? 5 ?? m ? 2 ?l_p$$

$$W \; ? \; 3.332 ? 10^{? 5}\,m$$

Width of the base section (P-doped)

$$? ?? 1 ? \frac{1}{2} ?? \frac{W ? 2 ?l_p}{l_{P\_D}} ?^2$$

$$? \; ? \; 0.995$$

Voltage Gain = ?

$$? ?? \frac{?}{1 ? ?}$$

$$? \; ? \; 199$$

Governing Equations

$$n_p \; ? \; N_c \exp[(E_f \; ? \; E_g \; ? \; e?)k_B T]$$

$$n_n \; ? \; N_c \exp[(E_f \; ? \; E_g)k_B T]$$

$$p_n \; ? \; N_v \exp[(? E_f)k_B T]$$

$$p_p \; ? \; N_v \exp[(? e? \; ? \; E_f)k_B T]$$

$$? \; ? [\frac{k_B T}{e}]\ln[\frac{N_a N_d}{n_i^2}]$$